

S-6/PHSH/CC-13/23

TDP (Honours) 6th Semester Exam., 2023

PHYSICS

(Honours)

THIRTEENTH PAPER : CC - 13

Full Marks : 60

Time : 3 Hours

*Answer from **both** the Groups as directed.*

The figures in the margin indicate full marks.

*Candidates are required to give their answers
in their own words as far as practicable.*

GROUP—A

1. Answer *any* **six** of the following questions :

2×6=12

- (a) Define the term 'wave impedance'.
- (b) What do you understand by anomalous dispersion?
- (c) Calculate the skin depth for radio waves of wavelength 3 m (in free space) in copper, the electrical conductivity of which is 6×10^7 S/m.

(d) Why is the quantity $\epsilon_0 \frac{\partial E}{\partial t}$ referred to as a displacement current?

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[Turn Over]

(2)

- (e) What is the nature of emergent polarised light when circularly polarised light is passed through a quarter wave plate?
- ✓(f) What are ordinary and extraordinary refractive indices?
- ✓(g) Explain clearly the term 'specific rotation'.
- (h) Define the term 'numerical aperture'.

GROUP—B

There are *four* questions from Question No. 2 to Question No. 5. Answer either (a) **or** (b) from each question given below :

12×4=48

2. (a) (i) Starting from Maxwell's equations show that in a homogeneous isotropic dielectric medium of permittivity ϵ and permeability μ , the velocity of an electromagnetic wave is given by

$$v = \frac{1}{\sqrt{\mu\epsilon}} .$$

- (ii) Establish the boundary conditions that must be satisfied by the field vectors when an electromagnetic wave is incident at the interface between two dielectric media.

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[Continued]

(3)

- (iii) A plane electromagnetic wave travels in free space in negative z -direction with a propagation constant 20 rad/m , the amplitude of the magnetic field being $\frac{40}{377} \text{ A/m}$. At $t=0$ and $z=0$, the magnetic field has the direction $-a_y$. Give expressions for $\vec{E}$ and $\vec{H}$. Also find the frequency and the wavelength.

4+3+(3+1+1)=12

(OR)

- (b) (i) Show that $\vec{B} = \frac{1}{c} (\hat{n} \times \vec{E})$, where $\hat{n}$ is the unit vector in the direction of propagation and c is the speed of light in free space.

- (ii) Explain the physical significance of Maxwell's equations of electromagnetism.

- (iii) Derive the law of conservation of charge from Maxwell's field equations.

- (iv) Show that under a gauge transformation of vector potential $\vec{A}$ and scalar potential ϕ , the electromagnetic field equations are invariant.

3+3+3+3=12

(4)

3. (a) ✓ (i) Deduce Fresnel's laws of reflection and refraction from the electromagnetic theory of light.

✓ (ii) An electromagnetic wave is incident on the interface between two dielectric media. What are the boundary conditions that must be satisfied by the field vectors? Show that the frequency of the incident wave remains unchanged by reflection and transmission.

(iii) Explain the significance of Brewster's angle. Find the Brewster's angle for a glass-oil boundary for external and internal reflections. Given refractive index for glass 1.52 and that of oil 1.81.
 $3+(2+3)+(2+2)=12$

(OR)

(b) (i) Give Lorentz's theory of dispersion and find the connection between absorption and anomalous dispersion.

(ii) Write the equation of motion of an electron in a radiation field. What is radiation damping?

(iii) Show that high frequency electromagnetic wave propagate only a small distance inside a conductor.

(iv) Why is the refractive index of glass for X-rays less than unity?

$$(2+3)+(1+2)+2+2=12$$

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[Continued]

(5)

4. (a) (i) Discuss the phenomenon of double refraction) and (describe in detail what happens when a ray of light is allowed to pass successively through two glass plates of calcite, the second being rotated about the incident beam. Show that the intensity of the emergent beam is same as that of the incident beam.)

(ii) Explain the working of quarter wave and half wave plate. Also calculate their thickness.

(iii) How will you distinguish between elliptically polarised light and a mixture of plane polarised and unpolarised light?

$$(3+2)+(2+2)+3=12$$

(OR)

(b) (i) Describe the construction, working and use of Nicol prism.

(ii) Explain how you would detect beams of circularly and elliptically polarised lights.

(iii) Linearly polarised light is changed into circularly polarised light after passing through a slice of crystal 2.5×10^{-5} m thick. If the difference in refractive index for ordinary and extraordinary ray is 0.005, find the wavelength of light used.

$$(2+3+1)+(2+2)+2=12$$

(6)

5. (a) (i) Give Fresnel's explanation of rotation of plane of polarisation by an optically active substance.
- (ii) Describe the construction and principle of Laurent's half-shade polarimeter. How will you use it to find the strength of sugar solution?
- (iii) State Biot's law of Rotatory polarization.
- $3+(2+3+2)+2=12$

(OR)

- (b) (i) Derive the expression for field components of TE waves in rectangular waveguide.
- (ii) Why are circular waveguides not preferred over rectangular waveguides? What is meant by group velocity of the guided wave?
- (iii) A step index fiber has normalized frequency 26.6 Hz at a 1300 nm wavelength. If the core radius is $25 \mu\text{m}$. Find the numerical aperture.
- (iv) What are the advantages of single mode fibre over multiple mode fibre?

$4+(2+1)+3+2=12$

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S-6/PHSH/CC-14/23

TDP (Honours) 6th Semester Exam., 2023

PHYSICS

(Honours)

FOURTEENTH PAPER : CC - 14

Full Marks : 60

Time : 3 Hours

Answer from **both** the Groups as directed.

The figures in the margin indicate full marks.

Candidates are required to give their answers
in their own words as far as practicable.

GROUP—A

1. Answer any **six** of the following questions :

2×6=12

- ✓(a) Explain the analogy of black-body radiation with ideal gas.
- ✓(b) Mention the difference between Wien's distribution law and Rayleigh-Jeans law in relation with black body radiation.
- ✓(c) What is thermodynamic probability?
- ✓(d) What is Gibbs paradox?
- ✓(e) What is 'Fermi energy'? Does it depend on temperature?

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[Turn Over]

(2)

- (f) What do you mean by strongly degenerate Bose gas?
- (g) At same temperature, which will exert greatest and least pressure — a gas obeying MB statistics or a gas of bosons or a gas of fermions?
- (h) Show that at high temperatures the FD distribution reduces to MB distribution.

GROUP—B

There are *four* questions from Question No. 2 to Question No. 5. Answer either (a) **or** (b) from each question given below :

12×4=48

2. (a) (i) State the Planck's law of black body radiation. Deduce Rayleigh-Jeans law from Planck's law of black-body radiation.

(ii) What is radiation pressure? Show that the pressure due to diffuse black body radiation is one third of energy density of radiation. $P = \frac{1}{3} u$.

(iii) Calculate the black-body temperature of sun from the following data :
Stefan Constant = $1.37 \times 10^{-12} \text{ cal/cm}^2/\text{s}$, solar constant = $2.3 \text{ cal/cm}^2/\text{min}$, radius of the sun = $7 \times 10^{10} \text{ cm}$, distance between the sun and earth = $1.5 \times 10^{11} \text{ m}$

$$T_2 (0.50597 \times 10^{15})^{1/4} (2+2) + (1+4) + 3 = 12$$

(3)
(OR)

(b) (i) State and prove Kirchhoff's law in relation with black-body radiation.

(ii) What is meant by diffuse radiation?

(iii) Write the Planck's quantum hypothesis.

(iv) A black-body of a temperature of 1646 K has wavelength corresponding to the maximum emission λ_m equal to 1.78 micron. Find the temperature of the moon (assumed to be a black-body) if λ_m for the moon is 14 micron.

(1+4)+2+2+3=12

3. (a) (i) What is phase space? Show that the volume in phase space corresponding to a discrete quantum state is h^3 .

(ii) Derive the Maxwell velocity distribution law using MB statistics.

(iii) A system of distinguishable particles has two non-degenerate single particle energy states O and E . Show that at temperature $T = E/K_B \ln 2$, the probability of a particle occupying the excited state be half that occupying the ground state.

(2+2)+4+4=12

(4)
(OR)

(b) (i) State and prove Sackur-Tetrode equation.

(ii) Show that the partition function for a monoatomic ideal gas is given by

$$Z = \frac{V}{h^3} (2\pi m k_B T)^{\frac{3}{2}}$$

Where symbols have their usual meanings (consider MB statistics).

(iii) Distinguish between mathematical probability and thermodynamic probability.

(iv) What are the limitations of MB statistics?
(1+4)+3+2+2=12

4. (a) (i) Name the statistics (BE or FD) obeyed by each of the following particles; neutron, π -meson, photon, neutrino.

(ii) What do you understand by Bose Einstein condensation? Calculate the critical temperature at which the condensation will start.

(iii) Write the properties of liquid helium.
2+(2+5)+3=12

(5)
(OR)

(b) (i) Derive Planck's law of black-body radiation using Bose-Einstein statistics.

(ii) Show that maximum entropy of a photon gas is given by

$$S_{\max} = \frac{4V\pi^2 K_B^4 T^3}{45\hbar^3 dc^3}$$

Where symbols have their usual meanings.

(iii) Discuss the difference between Fermi-Dirac and Bose-Einstein statistics.

5+5+2=12

5. (a) (i) Write the basic-assumptions of FD statistics. Derive the expression for Fermi-Dirac distribution law.

(ii) Show that for a two-dimensional electron gas, the number of electrons per unit area is given by

$$n = \frac{4\pi K_B T}{h^2} \ln \left(e^{\frac{E_F}{K_B T}} + 1 \right)$$

(2+5)+5=12

(6)
(OR)

- (b) (i) Write down the distribution law obeyed by electron gas and apply the same to derive Richardson-Dushman equation.
- (ii) Show that if f is the FD distribution function, $-\frac{\partial f}{\partial E}$ is a maximum at Fermi level. Also show that $-\frac{\partial f}{\partial E}$ is symmetric about the Fermi level. $(1+5)+(3+3)=12$

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S-6/PHSH/DSE-III/23

TDP (Honours) 6th Semester Exam., 2023

PHYSICS

(Honours)

THIRD PAPER : DSE – III

Full Marks : 80

Time : 3 Hours

*Answer from **both** the Groups as directed.*

The figures in the margin indicate full marks.

*Candidates are required to give their answers
in their own words as far as practicable.*

GROUP—A

1. Answer *any* **eight** of the following questions :
2×8=16

✓(a) Define Poisson Brackets.

(b) Is four-momentum always conserved?
Justify your answer.

✓(c) Write the Euler-Lagrange equation and
mention its significance.

✓(d) What is meant by “Minkowski Space”?

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[Turn Over]

(2)

- (e) An electron and a positron, practically at rest, come together and annihilate each other, producing two photons of equal energy. Find the energy and equivalent mass of each photon.
- ✓ (f) What do you mean by 'normal coordinate'?
- ✓ (g) Write the difference between compressible flow and incompressible flow in fluid.
- ✓ (h) A particle is moving with a speed such that the KE is half of the rest mass energy. Find the speed of the particle. $v \ll c$
- ✓ (i) Define 'cyclic coordinate'.
- (j) Write the Navier-Stokes equation of motion.

GROUP—B

There are *four* questions from Question No. 2 to Question No. 5. Answer either (a) **or** (b) from each question given below :

16×4=64

2. ✓ (a) ✓ (i) What are generalised coordinates?
✓ Write the advantages of using them.
- ✓ (ii) State Hamilton's principle for a conservative system. Using this principle, establish the Lagrange's equation of motion.

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[Continued]

(3)

- ✓(iii) A particle of mass m is projected with initial velocity u , at an angle θ with the horizontal axis. Use Lagrange's equation to describe the motion of the projectile. The resistance of the air may be neglected. $(2+2)+(1+5)+6=16$

(OR)

- (b) (i) What do you mean by 'constraints'? How do they affect the motion of a mechanical system?
- (ii) Explain the term 'Hamiltonian'. Hence deduce the Hamilton's canonical equation of motion.
- (iii) Show that the transformation

$$P = \frac{1}{2}(p^2 + q^2); \quad Q = \tan^{-1} \frac{q}{p}$$

is canonical. $(2+2)+(2+4)+6=16$

3. (a) (i) Deduce the relativistic expression for kinetic energy and show that for low velocity it reduce to the classical expresion for kinetic energy with mass replaced by rest mass.
- (ii) Write the expression of momentum of photon and from this relativistically, prove the existance of massless particle.

(4)

- (iii) Two electrons are moving in opposite direction with velocity $0.67c$ and $0.68c$ with respect to the sample. Find the relative speed of one electron with respect to other from classical and relativistic points.
- (iv) Why are the elementary particles point mass? Explain from relativistic point of view. $(4+2)+(1+3)+(1+3)+2=16$

(OR)

- (b) (i) With a clear diagram, explain world line world point.
- (ii) Explain the time dilation and length contraction.
- (iii) Why is twin paradox a paradox?
- (iv) What is four-momentum? (Show that the four dimensional volume element is invariant under Lorentz transformation.) How does the energy momentum relation relate to the concept of mass energy equivalence? $3+3+2+(2+3+3)=16$

4. (a) (i) Write down the Maxwell's equation in 4-dimensional form. Hence show that they are invariant under Lorentz transformation.

(5)

(ii) Show the relativistic invariance of $\vec{E} \cdot \vec{B}$.
Write down the physical significance of it.

(iii) Define four-vector. Discuss the decay of unstable particle in the context of four-vector. $(2+4)+(3+2)+(2+3)=16$

(OR)

(b) (i) Write down the equations for field tensor.

(ii) Show that Lorentz transformation is covariant for the first pair of Maxwell's

equation $\text{div } \vec{B} = 0$ and $\text{curl } \vec{E} = -\frac{\partial \vec{B}}{\partial t}$.

(iii) Using relativistic transformation, derive the expression of electric field due to a uniformly moving charge.

(iv) If total charge is an invariant quantity, how can it be that a neutral wire in one frame appears to be charged in other frame? Suppose that an electric field is purely electric in inertial frame S; i.e. $E \neq 0$, $B = 0$; Describe the nature of the field in inertial frame S'.

$2+4+5+(2+3)=16$

[Turn Over]

(6)

✓ 5. (a) (i) Define stable equilibrium and unstable equilibrium on the basis of its potential function. Explain it with suitable example.

(ii) Express the kinetic and potential energies of a system in terms of normal coordinate.

(iii) What are the basic properties of a fluid? Describe the factor that can influence the pressure distribution within the fluid. Explain the relationship between density and pressure in a fluid.

$$(3+2)+5+(2+2+2)=16$$

(OR)

✓ (b) ✓ (i) Define laminar and turbulent flows in fluid. Explain it with suitable example.

✓ (ii) Deduce the equation of continuity for the motion of the fluid.

✓ (iii) What is Reynolds number? How is it used in fluid mechanics?

✓ (iv) Write down the significance of Navier-Stokes equation in fluid mechanics.

$$(3+2)+5+(2+2)+2=16$$

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S-6/PHSH/DSE-IV/23

TDP (Honours) 6th Semester Exam., 2023

PHYSICS

(Honours)

FOURTH PAPER : DSE – IV

Full Marks : 80

Time : 3 Hours

*Answer from **both** the Groups as directed.*

The figures in the margin indicate full marks.

*Candidates are required to give their answers
in their own words as far as practicable.*

GROUP—A

- 1. Answer any **eight** of the following questions :**
2×8=16

- ✓(a) What do you mean by nanostructured material?
- ✓(b) Write the importance of defects in nanomaterials.
- ✓(c) Draw the variation of Density of State (DOS) as a function of energy for 0-d and 2-D nanoparticles.
- ✓(d) What do you mean by radiative and non-radiative transitions?

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[Turn Over]

(u)

(2)

✓(e) What is physical vapour deposition technique?

(3)

(f) What is fluorescence?

✓(g) Can excitons be considered as quasiparticles? Justify your answer.

✓(h) What are nanowires? What unique properties do they possess at nanoscale?

(i) What properties of nanoparticles make it useful in the development of high performance electronic display?

✓(j) Define magnetoresistance.

GROUP—B

There are *four* questions from Question No. 2 to Question No. 5. Answer either (a) **or** (b) from each question given below :

16×4=64

✓2. (a) (i) How are the nanoscale systems different from bulk systems? Explain.

(ii) How are the nanoscale systems used in medicine and healthcare?

(iii) What are nanodots? What unique properties do they exhibit at the nanoscale?

(3)

- (iv) What is tunnelling conductivity? How does it occur in nanoscale system? What factor influence the tunnelling conductivity of nanoscale structure?

$$3+3+(2+2)+(2+2+2)=16$$

(OR)

- (b) (i) Explain the phenomenon of coulomb blockade in nanoscale system.

- (ii) Explain the consequences of quantum confinement.

- (iii) How do nanowires differ from nanorods in terms of their structure and properties?

- (iv) What is hopping conductivity? How does it occur in nanoscale system? How does it differ from metallic conductivity?

$$3+3+(2+2)+(2+2+2)=16$$

3. (a) (i) What is ball milling? How does it affect the structure, size and properties of nanoparticles? (Write the advantages of using ball milling for nanomaterial synthesis compared to other methods)

- (ii) What is top-down and bottom-up approach in nanoscience? Write the differences between these two techniques.

(4)

- ✓(iii) Explain the working theory of SEM technique. $(2+2+2)+(2+2+2)+4=16$

(OR)

- (b) (i) What are the key principles and processes involved in thermal evaporation, a type of physical vapour deposition technique? Write the advantages of this technique.

- (ii) How does the sol-gel process contribute to the synthesis of nanomaterials? What are the key factors that influence the stability and homogeneity of sol-gel derived nanomaterials?

- (iii) What information can we get from SEM image of nanomaterials?

$$(2+3+3)+(3+3)+2=16$$

- ✓4. (a) ✓(i) What are quasiparticles? How do they differ from elementary particles?

- (ii) How do excitons and quasiparticles contribute to the understanding of optical properties and energy transfer in materials?

- (iii) Write short notes on (a) surface plasmon resonance and (b) lithography.

$$(2+2)+(3+3)+(3+3)=16$$

(5)
(OR)

(b) (i) What do you mean by Morse potential energy curve? Explain graphically.

(ii) State and prove Beer-Lambert's law. What are the limitations of it?

(iii) What is Luminescence? Write the difference between electroluminescence and photoluminescence.
 $(2+2)+(1+3+2)+(2+4)=16$

5. (a) (i) Describe the working theory of a solar cell with schematic diagram.

(ii) How do different nanomaterials (both organic and inorganic) impact the performance of solar cell in terms of its figure of merit?

(iii) Explain the working of LEDs to achieve high efficiency light emission. Write two practical applications of LED.

$$5+5+(5+1)=16$$

(OR)

(b) (i) What is magnetic quantum well? How does it differ from a traditional quantum well structure? What are the unique properties and behaviours exhibited by electrons in a magnetic quantum well due to the presence of magnetic field?

(6)

(ii) Do a comparative analysis of quantum dots, nanowires and thin films with respect to the application in photonic devices.

(iii) What is optical switching?

$$(2+2+2+2)+6+2=16$$

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